ChemTalk

CHANGES OF STATE

All matter is made up of tiny particles. Different materials are made of different kinds of particles. These particles are always moving, and there are spaces between them. The more energy the particles have, the faster they move. There are also attractive forces among the particles. The closer the particles are together, the greater are the attractive forces.

Temperature

Chem Words

temperature: the measure of the average kinetic energy of all the particles of the material.

kinetic energy: a form of energy related to the motion of a particle ($KE = \frac{1}{2}mv^2$).

You get an intuitive sense of **temperature** by how hot or cold something feels to your skin. Your body is at 37°C (98.6°F). When something with a higher temperature comes in contact with your skin, you know that it is "hot." When something with a lower temperature comes in contact with your skin, you know that it is "cold." As you observed in the activity, when the temperature of air increased, the drop of water lifted. This drop of water could be a crude thermometer. As the drop rises, you know that the temperature of the air is higher. Liquids like alcohol and mercury expand when they get hot and are used for the thermometers with which you are most familiar.

The movement of the water drop gives you an insight into another interpretation of temperature. The air molecules inside the tube were moving faster as the temperature of the air increased. The temperature of the air is a measure of the speed of the molecules. In physics, you learned that kinetic energy is related to speed. **Kinetic energy** is equal to one-half the mass times the square of the speed of the particles ($KE = \frac{1}{2}mv^2$). Observing the behavior of many gases, scientists have concluded that temperature is a measure of the average kinetic energy of the molecules.

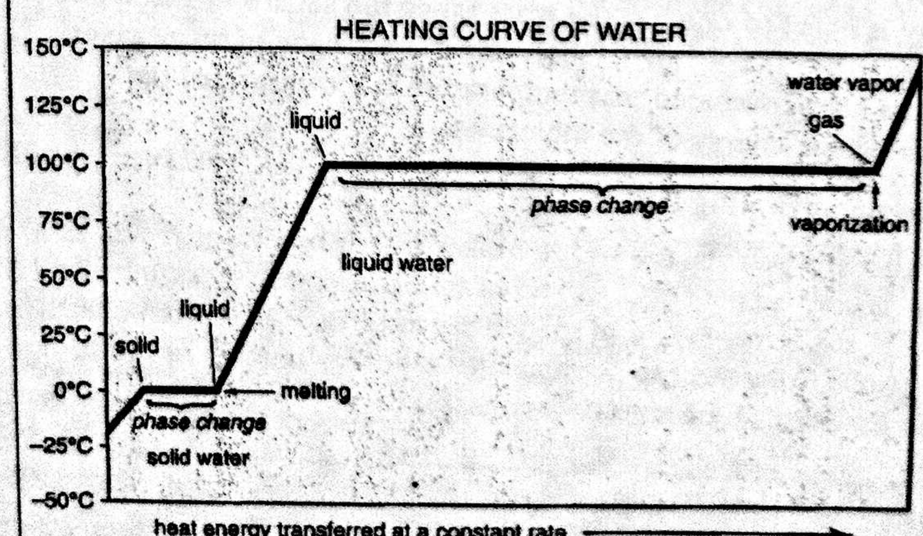
Melting and Boiling Points

In this activity you started with a beaker of crushed ice that was at a temperature less than 0°C. As you heated the ice it did not initially melt, but the temperature of the ice began to rise. As the temperature of any solid increases, the average kinetic energy (energy of motion) of the particles of the material increases.

This motion is mainly a vibration-type motion where the molecules vibrate around a fixed location. As heat energy continued to be transferred, the temperature of the ice increased until it reached 0°C. This is called the **normal melting point** of water. It is the temperature at which water changes from a solid to a liquid state at 1 atm (atmospheric pressure at sea level). It is also the **normal freezing point** of water, when water changes from a liquid to a solid at 1 atm. Each material has its own characteristic normal melting/freezing point.

The temperature then remained at 0°C as the solid water changed to a liquid. Since the temperature remained constant, the average kinetic energy did not change. All the heat energy that was transferred caused a phase change during which the molecules of water were rearranging or decomposing. There was a change in the **potential energy**. If there is a change in kinetic energy you will see a change in temperature and if there is a change in potential energy, the temperature will remain constant while heat energy is transferred to a material.

When all of the water had melted at 0°C, the temperature of the liquid water increased until it reached 100°C. This is called the **normal boiling point** of water at 1 atm.



Chem Words

normal melting point: the characteristic temperature, at 1 atm, at which a material changes from a solid state to its liquid state.

normal freezing point: the characteristic temperature, at 1 atm, at which a material changes from a liquid state to its solid state.

potential energy: stored energy of the material as a result of its position in an electric, magnetic, or gravitational field.

normal boiling point: the temperature at which the vapor pressure of the pure liquid equals 1 atm.

If the atmospheric pressure is less than 1 atm, then the water will boil at less than 100°C and is just called the boiling point of the liquid. For example, on Mt. Rainier in Washington State, at an altitude of about 4393 m (14,411 ft), the atmospheric pressure is much less than 1 atm, and you would find that water boils at a lower temperature.

When the water arrived at the boiling point, you again noted that the temperature remained the same, even though heat energy was still being transferred to the water. The temperature would remain the same until all of the liquid is **vaporized.** Then, with additional heat energy, the temperature would again increase and the gas molecules of water would have greater average kinetic energy.

Chem Words

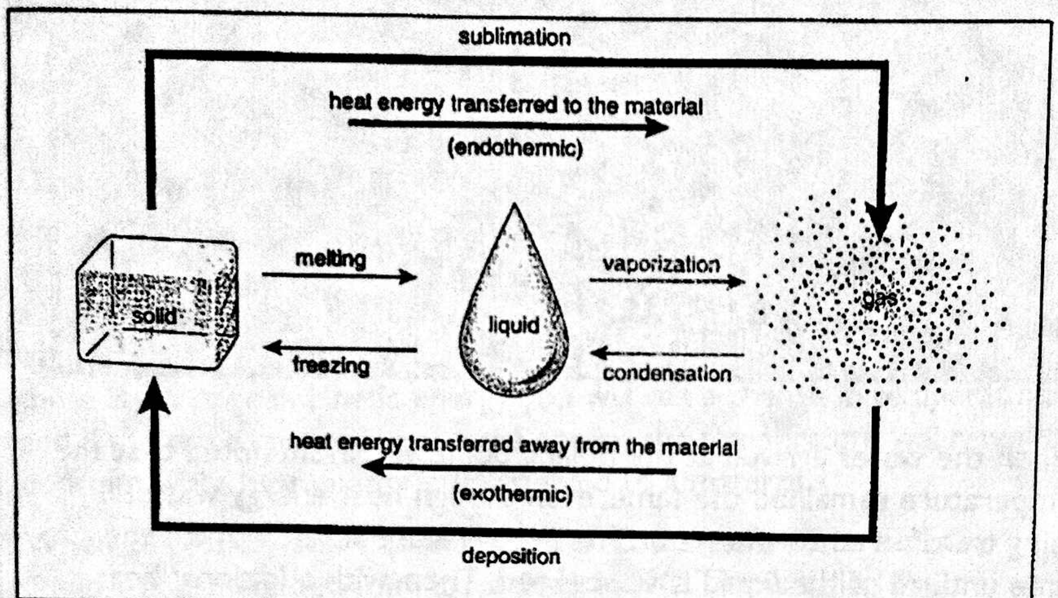
vaporization: the change of state from a liquid to a gas.

sublimation: the change of state of a solid material to a gas without going through the liquid state.

Heating Curve of Water

These changes in the temperature of a material, as heat energy is transferred to it, can be summarized in a graph, similar to the one you constructed. The heating curve of water is shown in the diagram on the previous page. The length of the first horizontal section corresponds to the amount of heat energy required to make the material change from solid to liquid.

Dry ice (solid carbon dioxide) that your teacher used in the demonstration, does not have a normal melting point; instead, it has a normal sublimation point (-78.5°C at 1 atm). **Sublimation** is the process where the solid goes directly to the gaseous state. The changes of state are summarized in the diagram below.

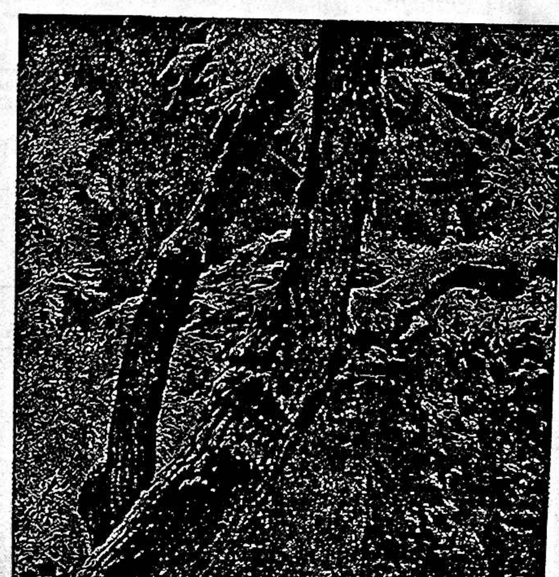


Checking Up

1. What does temperature measure?
2. Describe what is happening to particles of a material when heat energy is transferred to the material and the temperature increases.
3. What happens to the temperature of a material when it is undergoing a change of state?
4. What is the difference between the normal boiling point of water, and the temperature at which water might boil?

Reflecting on the Activity and the Challenge

In this exercise you focused on very simple chemistry, the motions of particles in solids, liquids, and gases. You can use the techniques learned in this activity to animate more complicated chemical systems. Consider how you could illustrate a phase change, like boiling or freezing. With research you might be able to use animation to explain the chemistry you use in staging your special effect.



Chemistry to Go

1. Copy and complete the following table summarizing the changes of state ~~in your *Active Chemistry* log.~~ ON A PIECE OF NOTEBOOK PAPER

Change of State	From	To	Heat (added or removed?)
boiling	liquid	gas	added
condensation	gas	liquid	removed
evaporation			
freezing			
melting			
deposition	gas		
sublimation	solid		
vaporization			

2. Copy and complete the following table ~~in your *Active Chemistry* log.~~ ON A PIECE OF NOTEBOOK PAPER

Definite or Indefinite?	Solid	Liquid	Gas
shape			
volume			

3. The heating curve for water was given in the ChemTalk reading section. Create the cooling curve for water and describe each part of the curve.

4. Create a heating curve for water when you have twice the amount of water you used in the investigation. How does this heating curve compare with the original curve?

5. The melting and boiling points of three materials are given on the next page.

   a) Draw a heating curve for each material.

   b) From graphs, explain why, at room temperature (22°C), copper is solid, mercury is liquid, and oxygen is a gas.

6. When water is in a pressure cooker the pressure is greater than 1 atm. What will the boiling point of water be compared to the normal boiling point of water? What information did you use to support your answer?